Vertical Movements and Sea Level Change in Alaska

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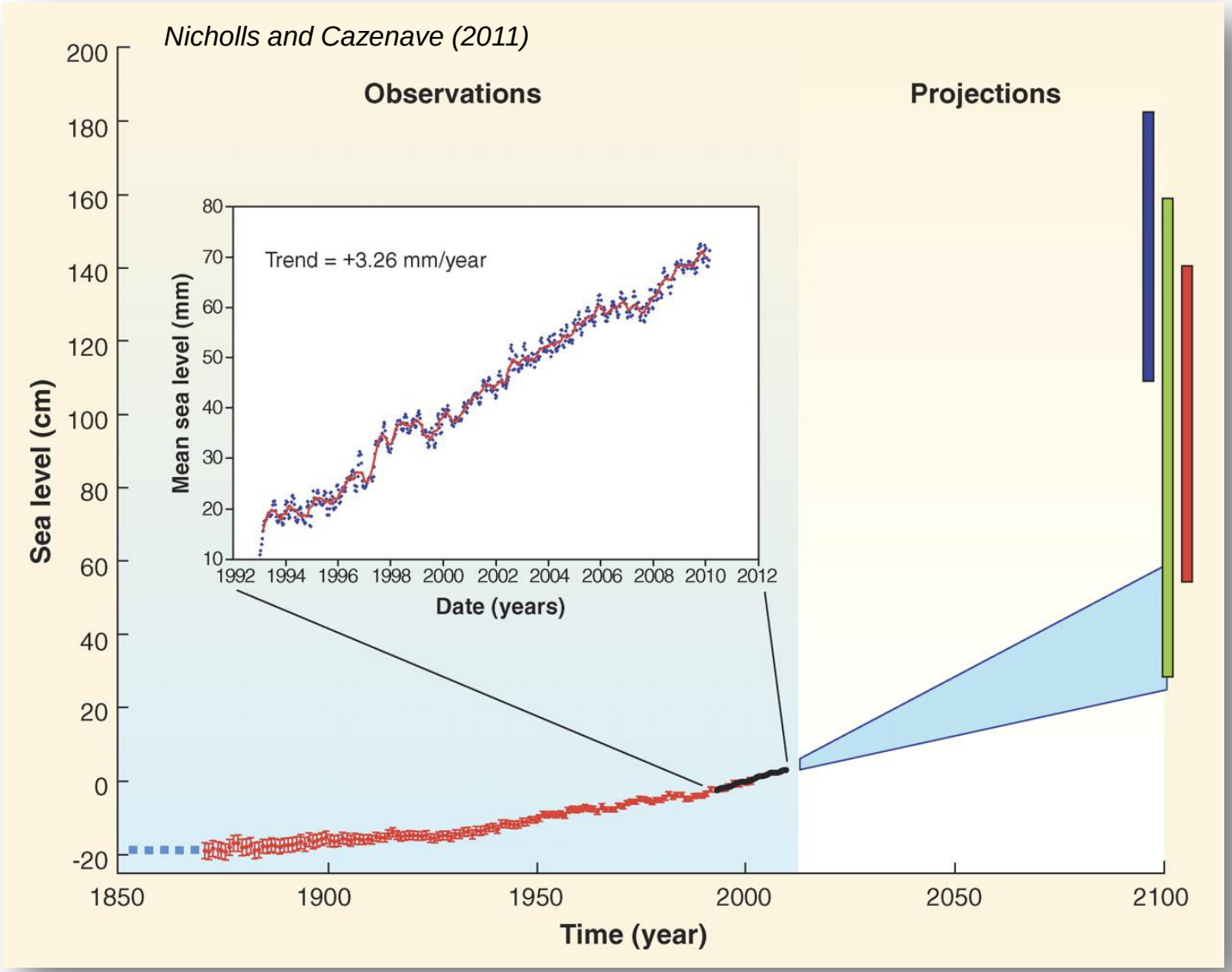
Topics

- Relative sea level is determined by both the level of the ocean and the level of the land
  - Both vary regionally
  - *The land surface in southern Alaska is moving faster than global sea level is presently changing*.
- Two most important factors in Alaska
  - Uplift caused by removal of ice load (Glacial Isostatic Adjustment).
  - Uplift and subsidence caused by tectonic motions and “earthquake cycle”

Global Mean Sea Level



Relative Sea Level

Relative Sea Level

- RSL = ***level of the sea*** minus ***level of the land***
- Both terms can vary regionally
  - Level of the sea: thermal expansion, addition of water, **gravity field**, oceanography
  - Level of the land: **tectonics**, **post-glacial rebound**, **changes in water/ice loading**, **compaction of sediments**, etc.
- In Alaska, land level changes are, in general, more rapid than sea level changes.

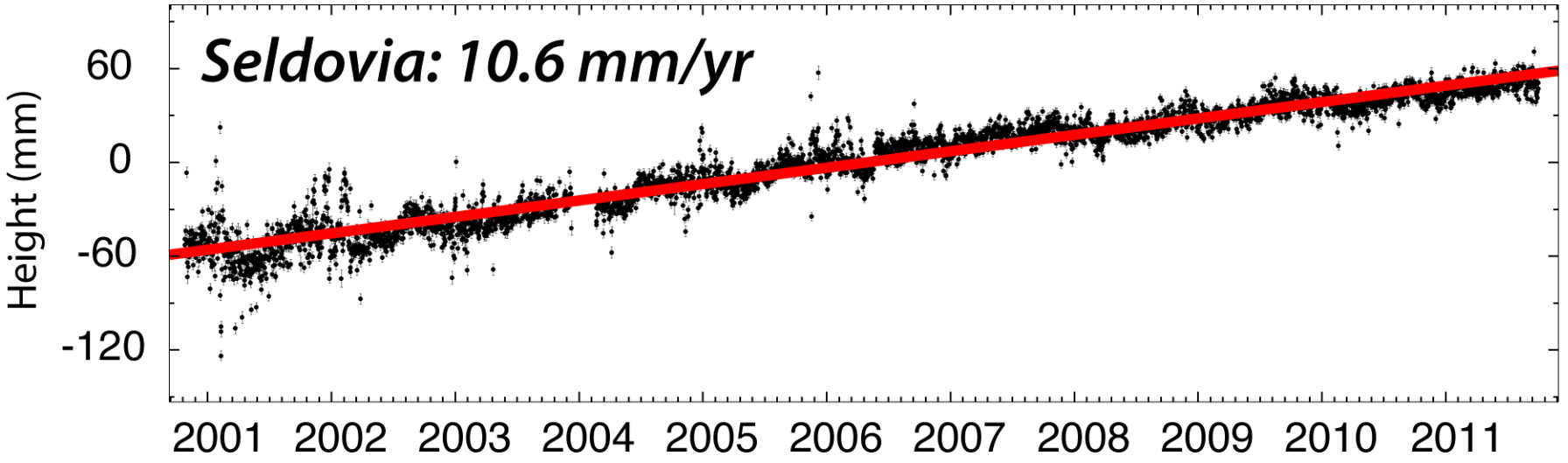
Measuring Land Level Changes

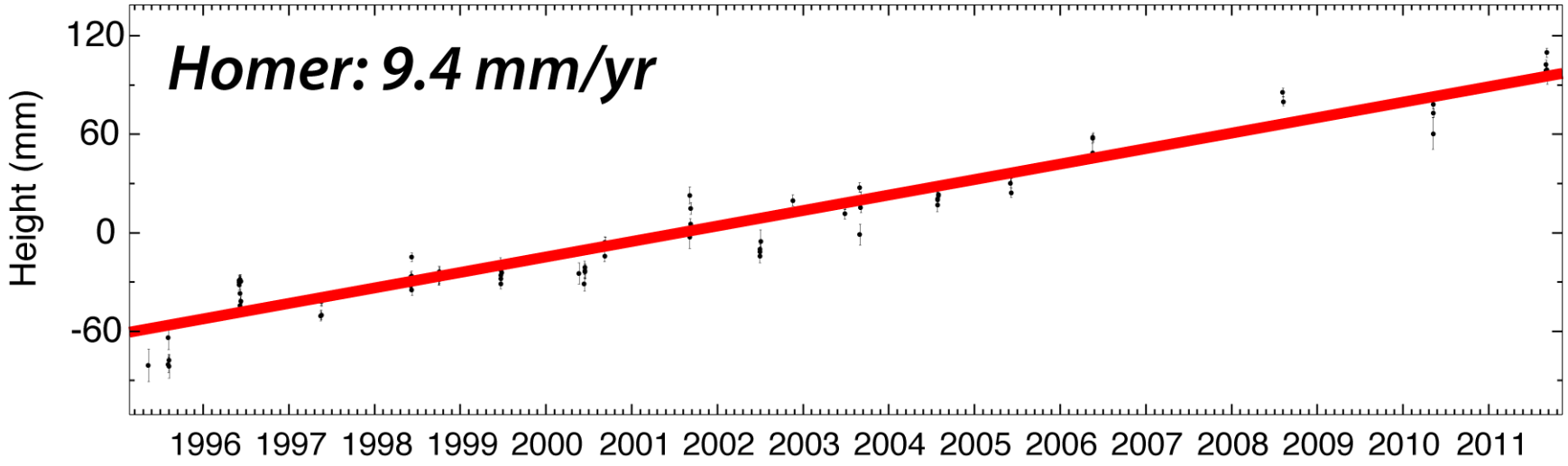
Global Positioning System

- Portable Surveying Equipment
- Precision of a few millimeters in 3D
- Repeated surveys measure motion of sites

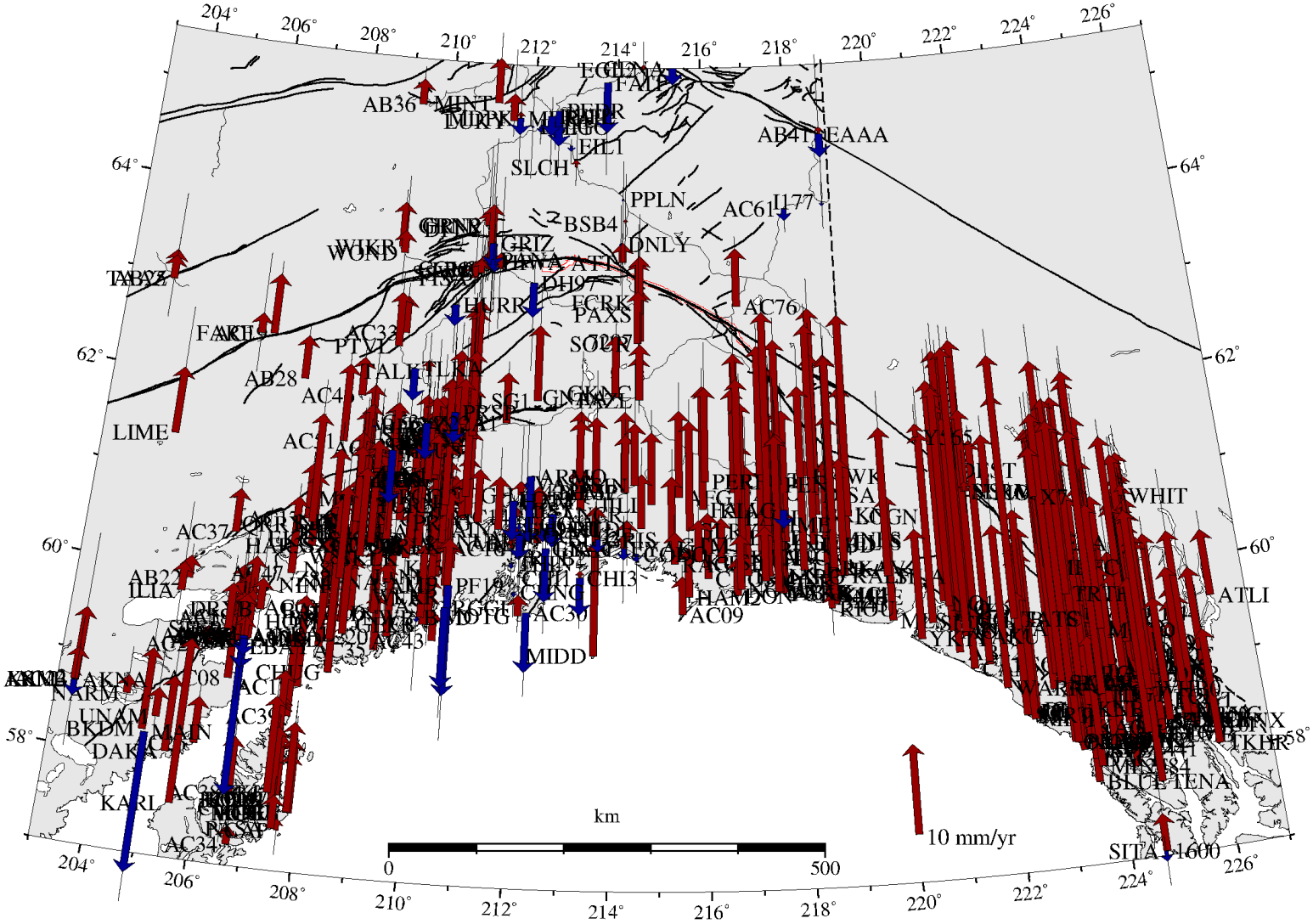
A Continuous Site Installation

Vertical Time Series



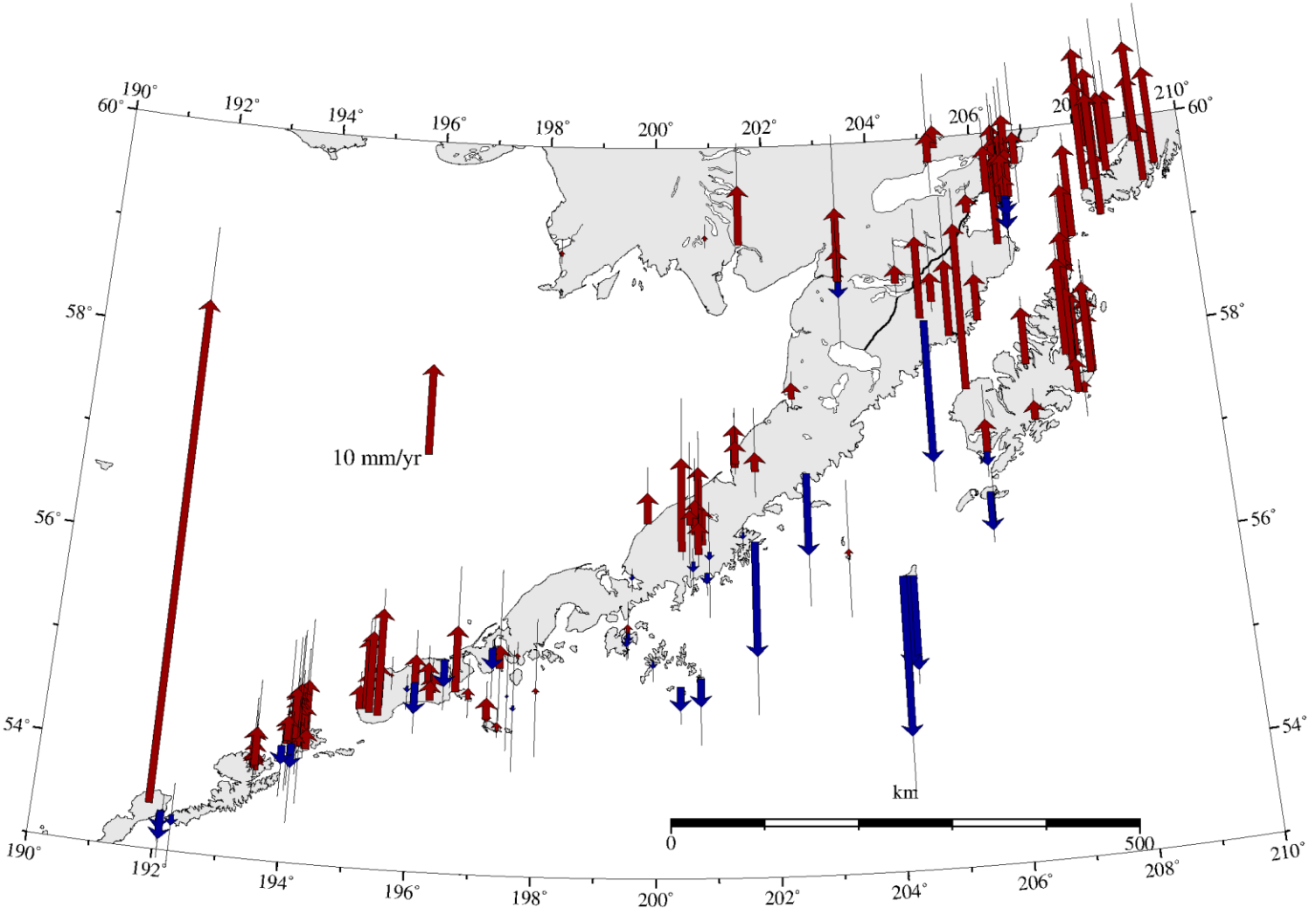


Uplift Rates – Southern Alaska



updated from Freymueller et al. (2008)

Uplift Rates – Southwest Alaska



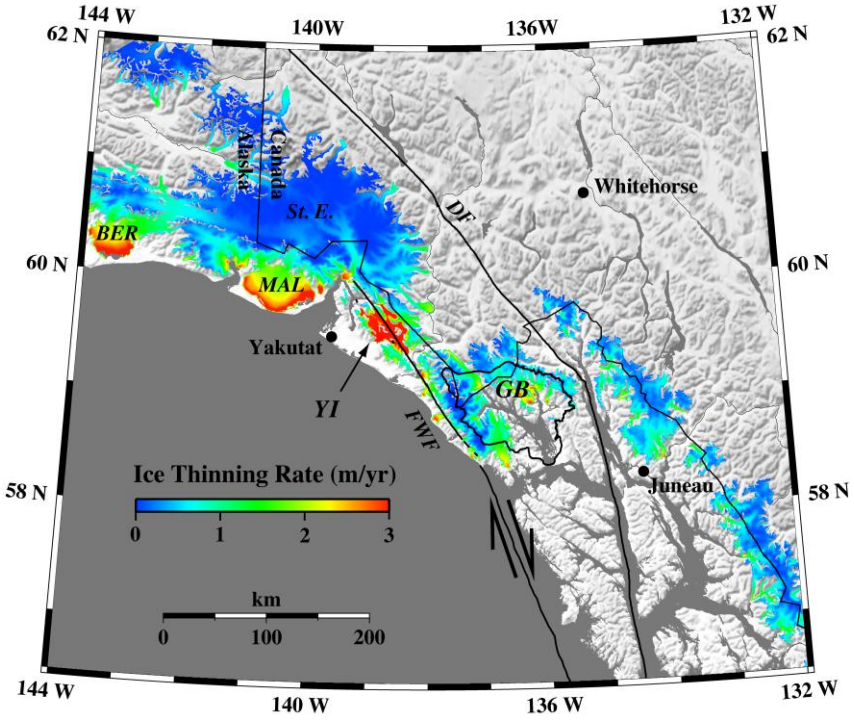
updated from Freymueller et al. (2008)

Main Causes of Uplift Locally

- Post-Glacial Rebound/Glacial Isostatic Adjustment
  - Uplift of the land caused by removal of ice load
    - Instant (elastic) response due to ongoing load changes
    - Time-delayed (viscous) response due to past load changes
- Tectonic effects
  - Deformation due to plate coupling at subduction zone
  - Uplift due to post-seismic deformation after 1964 earthquake

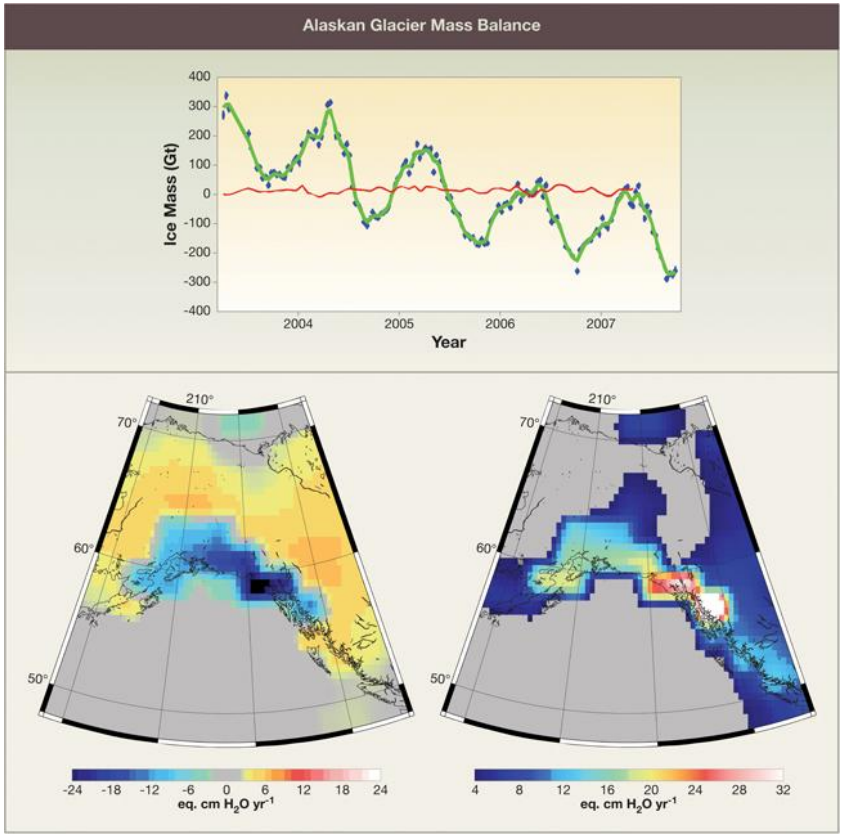
Post-Glacial Rebound – Melting Ice

From repeat glacial altimetry



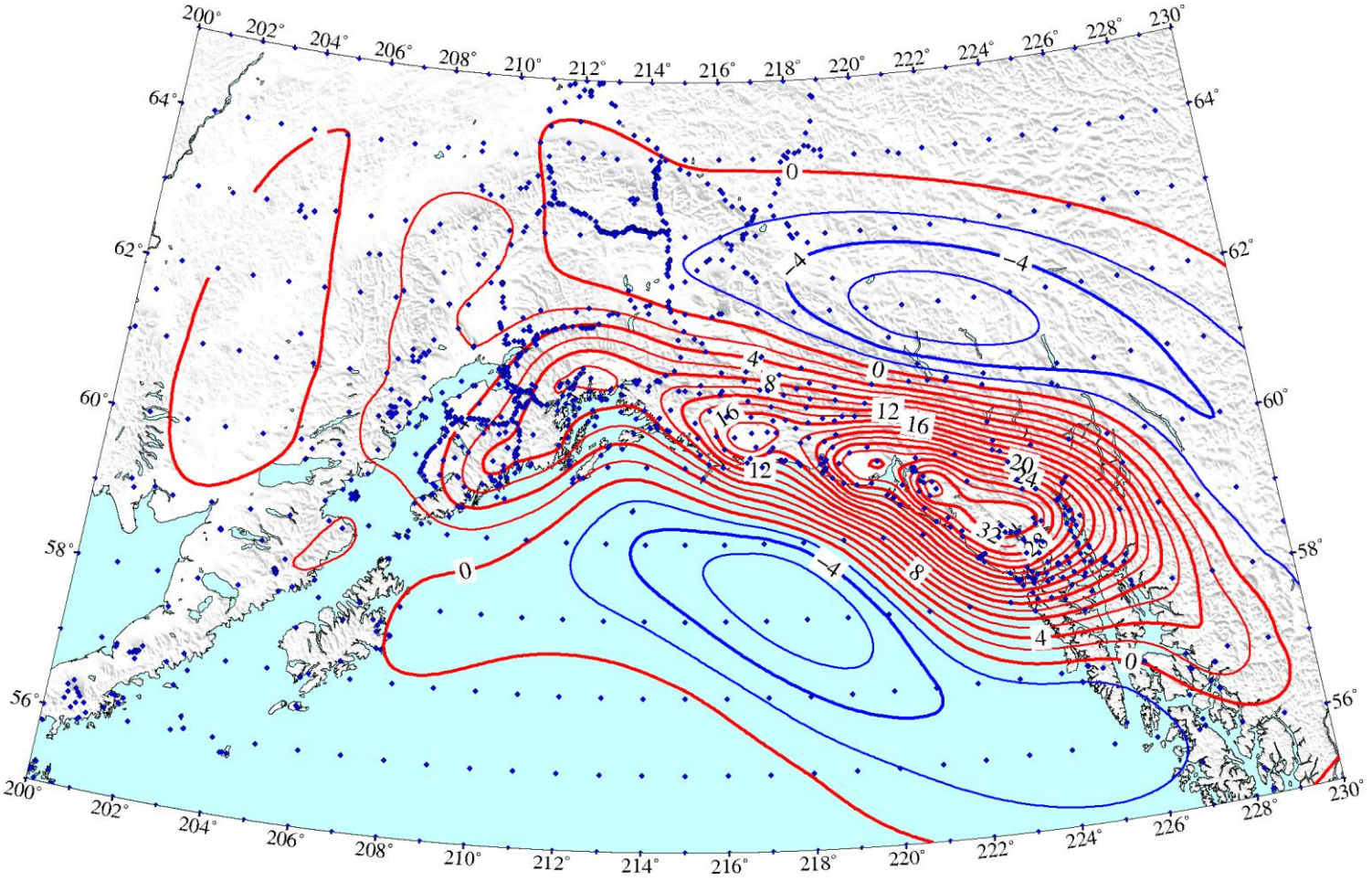
Arendt et al. (2002)

From geoid changes (GRACE)

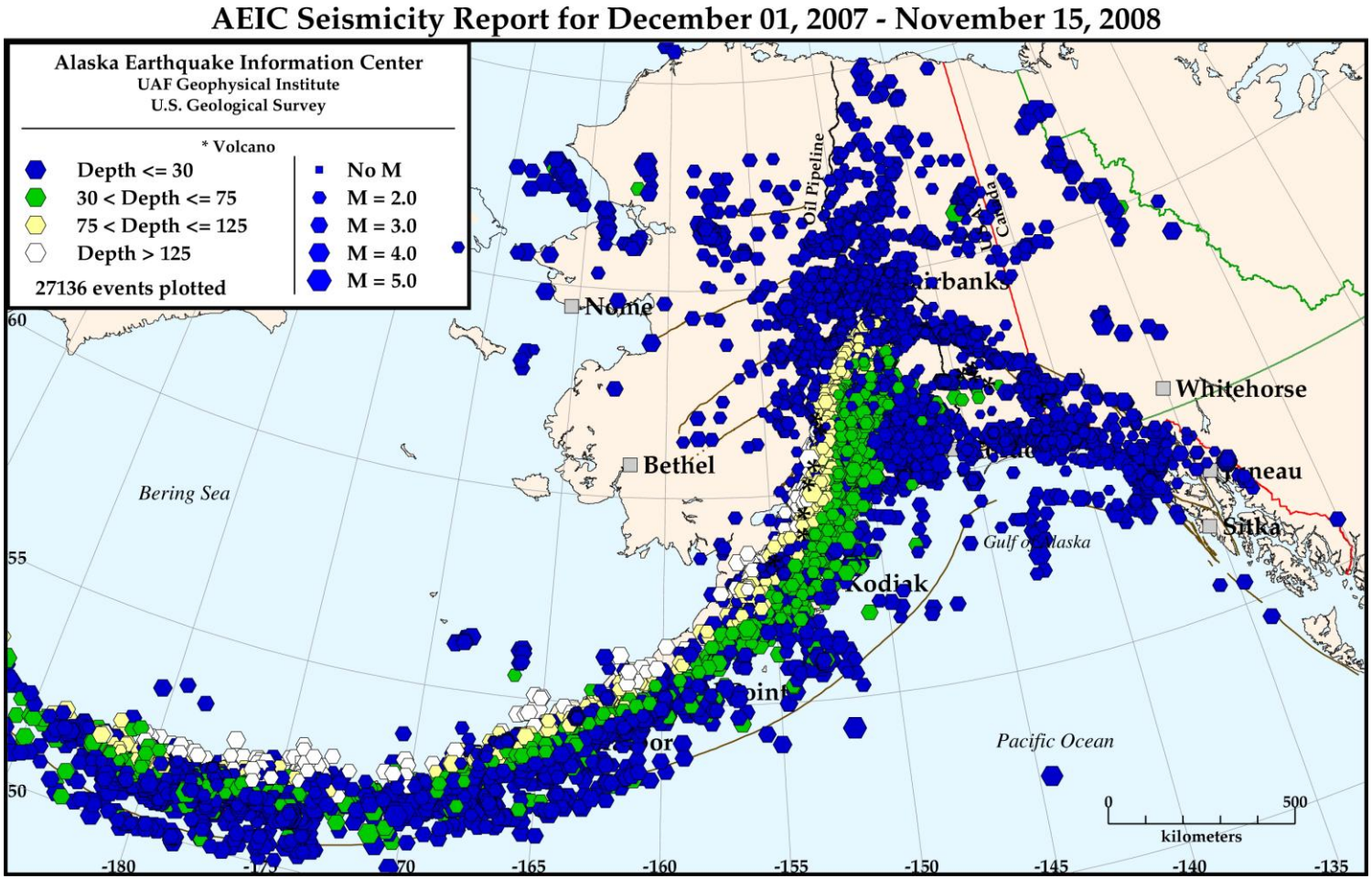


Luthcke et al. (2008)

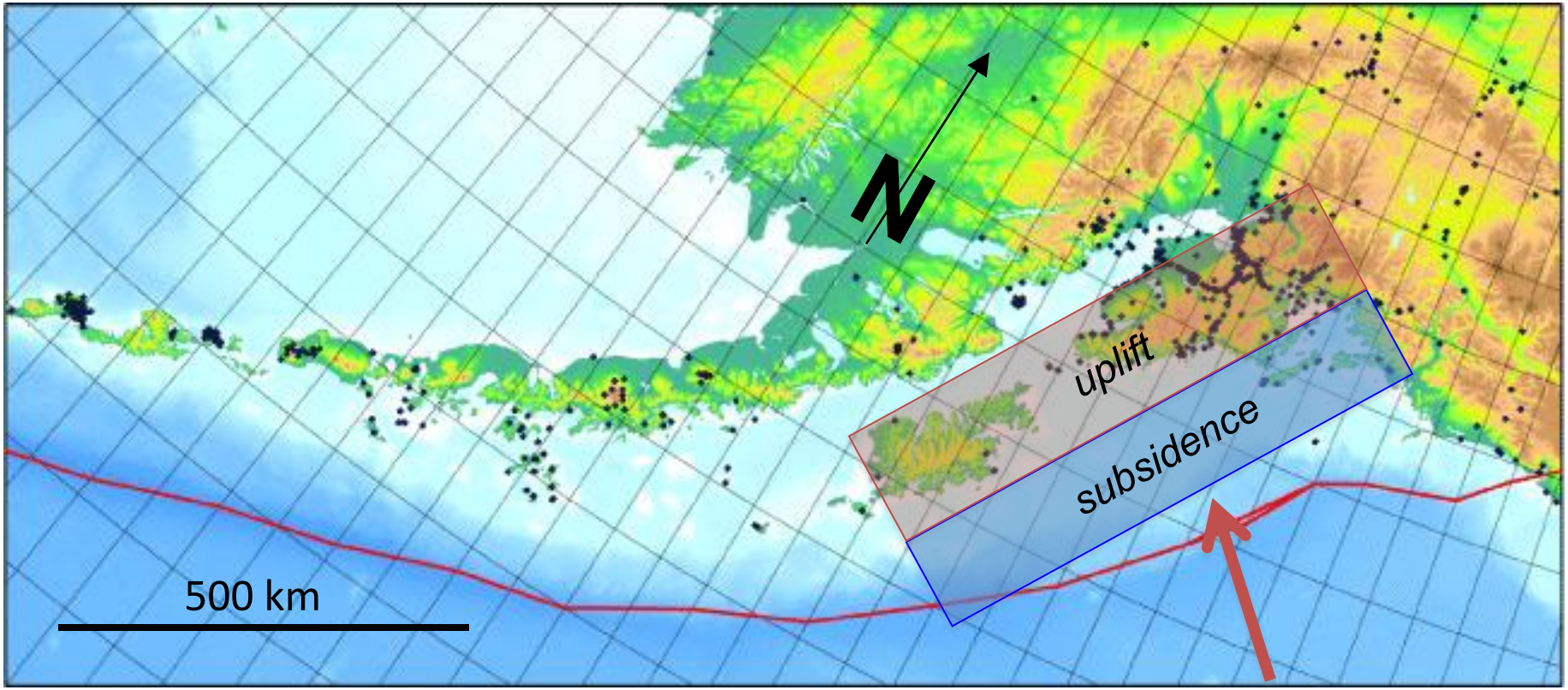
Predicted Uplift/Subsidence Rates



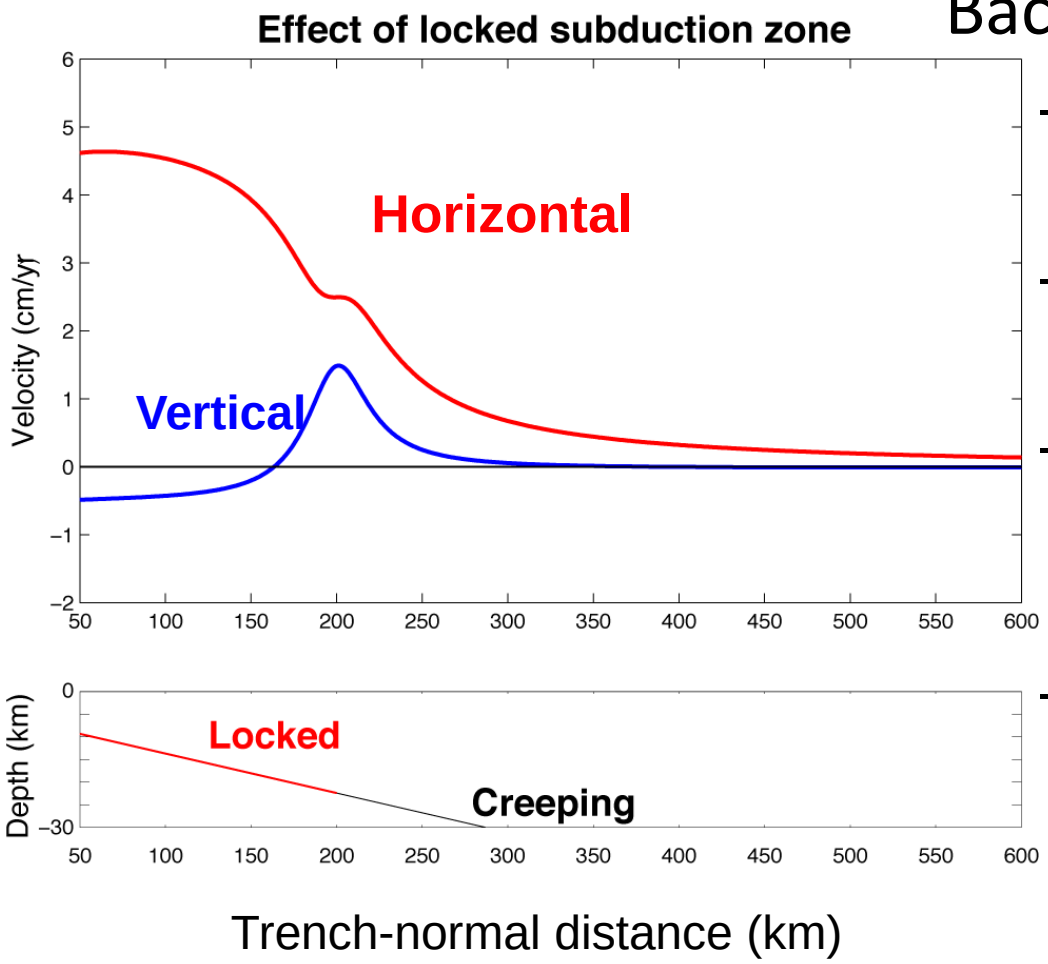
One Year's Seismicity



Deformation Pattern Between Earthquakes



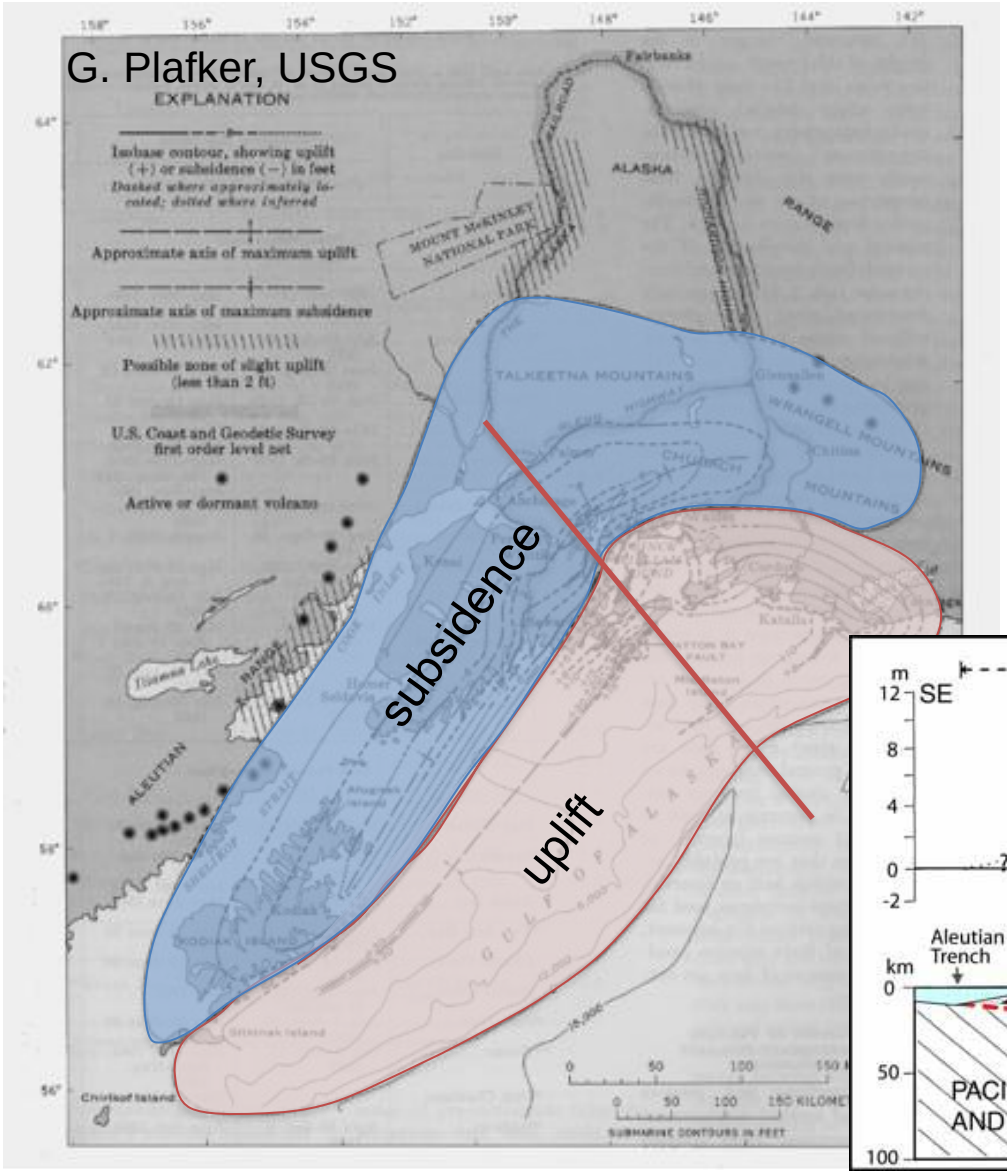
Deformation At Subduction Zone



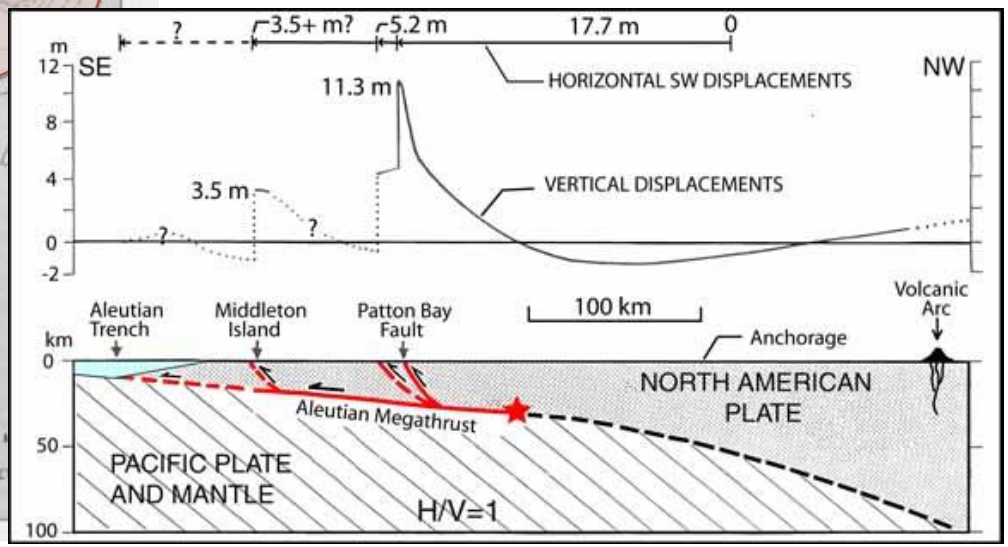
Backslip model (Savage, 1983)

- Shallow part of fault slips only in earthquakes
- Deeper part slips steadily at long-term rate
- Superposition of steady slip on entire interface and backslip (***slip deficit***)
- Earth deforms as elastic or linear viscoelastic body
  - Viscoelasticity of mantle introduces time dependence!

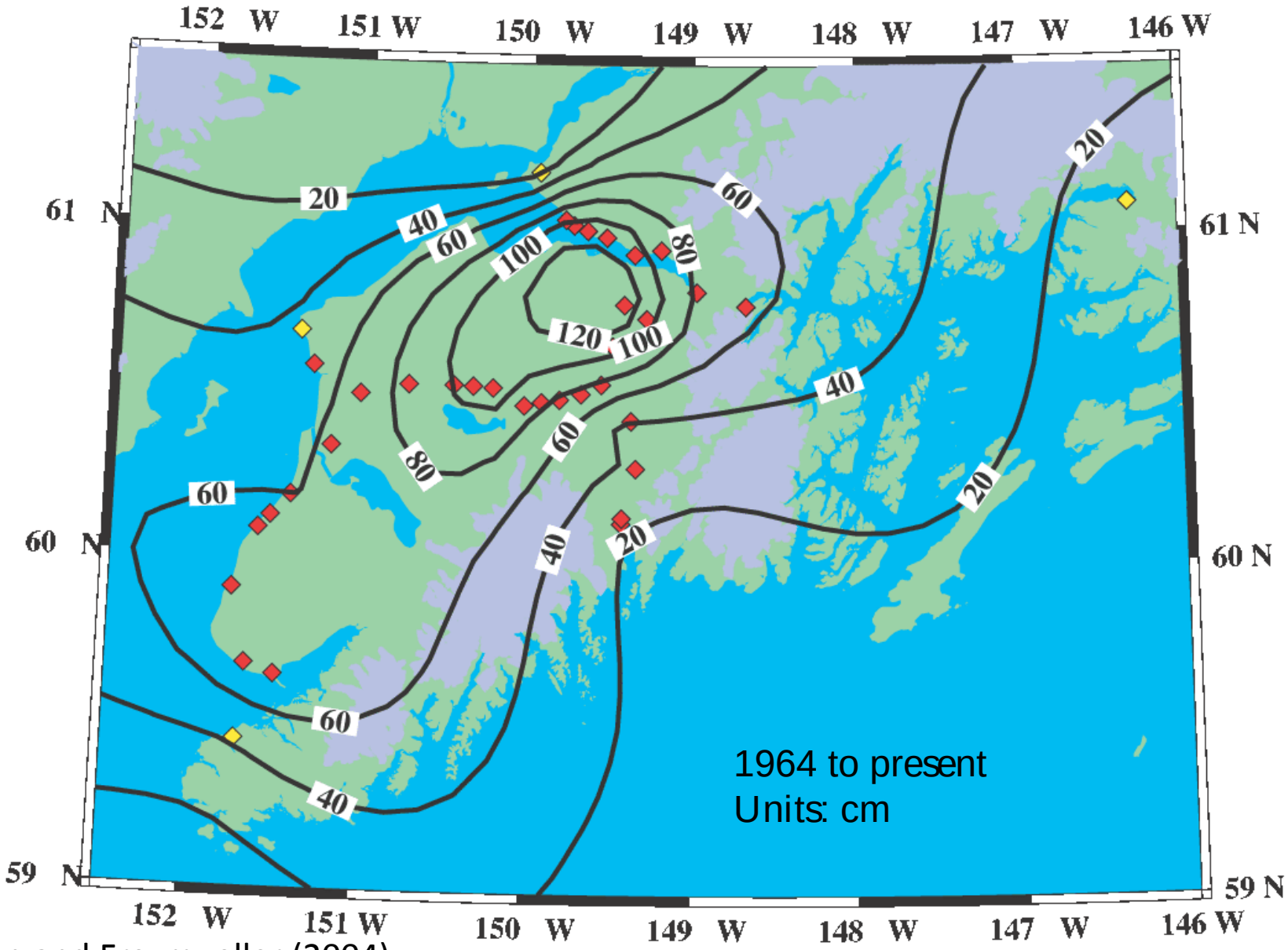
Subsidence in 1964



- Kachemak Bay lay near axis of maximum subsidence in 1964
- About 1 meter subsidence
- Cyclic pattern
  - Land here uplifts between earthquakes and subsides during earthquakes



Total Post-1964 Postseismic Uplift



Cohen and Freymueller (2004)

Regional Variations in Alaska

- ***Southeast***: Uplift due to glacial isostatic adjustment is many times faster than RSL.
- ***Prince William Sound***: Tectonic subsidence and rising sea level combine to produce rapid local sea level rise.
- ***Cook Inlet/Kenai Peninsula***: Tectonic uplift and some glacial isostatic adjustment means land is rising 2-4 times faster than sea
- ***Kodiak/Alaska Peninsula/Aleutians***: Paired belts of tectonic uplift and subsidence (offshore)
- ***Western Alaska***: Virtually no data

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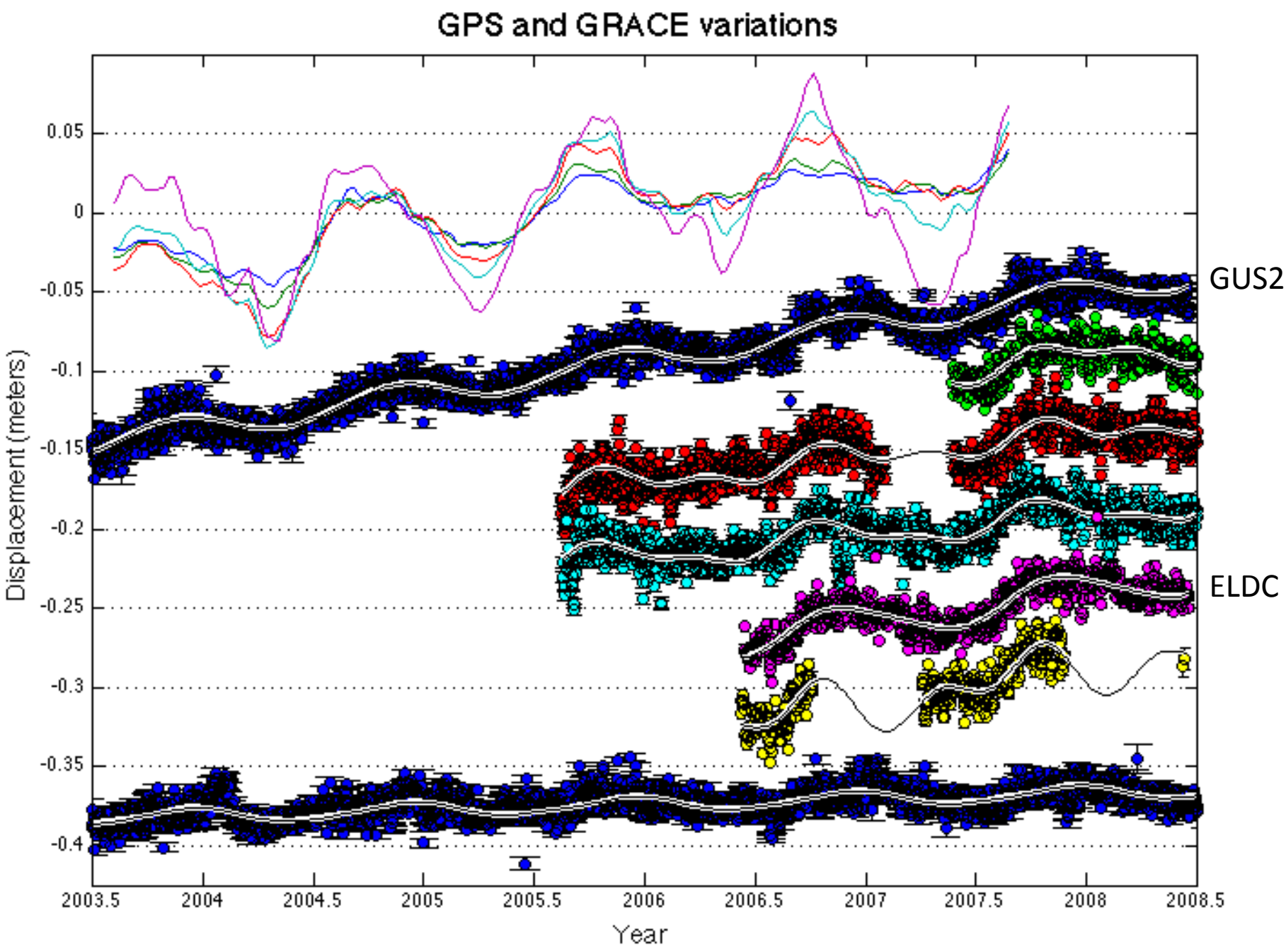
GPS and GRACE variations
Displacement (meters)
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
2003.5
2004
2004.5
2005
2005.5
2006
2006.5
2007
2007.5
2008
2008.5
Year
GUS2
ELDC

Regional Sea Level Trends
1992-2009

Nicholls and Cazenave (2011)